Ultra-Lightweight Telescope, Integrated Missions for Astronomy

Edward E. Montgomery/PS02
205–544–1767

The objective of the Ultra-Lightweight Telescope, Integrated Missions for Astronomy program is to achieve near-diffraction-limited images of astronomical objects at visible and/or infrared wavelengths with a space telescope having an ultra-lightweight primary mirror combined with large-amplitude, adaptive, correction optics. The program approach is to apply a stepwise process of technology developments on the ground and in space to advance the feasibility of constructing a very large aperture space telescope.

The technologies being developed will provide a system that can be transported to space in densely packaged form to fit existing launcher-payload envelopes, and then will be constructed/deployed to form space telescopes with large apertures. Such a system would also continually compensate for image distortions due to imperfections, natural disturbances, and equipment-induced vibrations/deflections. The goal will be to make possible very large primary reflectors of low mass and cost.

Proceeding from a set of telescope requirements established by a scientific working group from current needs in astronomy that includes cosmological investigations and the search for extra-solar planets, the technology program is going forward in two main thrusts: (1) large-aperture, thin-film mirror technology and (2) segmented adaptive correctors. The objective of the first thrust is to demonstrate the ability to form and maintain a thin-membrane primary reflector so that near-diffraction-limited performance is achieved over large areas sufficient to fill large primary apertures. The second objective is to demonstrate the ability to form and maintain a segmented quaternary mirror into a quasicontinuous surface with individual subapertures phased so that optical errors are compensated for and near-diffraction-limited performance is achieved in the telescope system.

Figure 1 shows several generations of adaptive, segmented-mirror technology developed over the last 5 years. In the upper left is a 7-centimeter-diameter, 4-centimeter-tall Phased-Array Mirror, Extendible Large Aperture—a half-meter aperture, 36-segment telescope demonstrator developed by Kaman under contract to the U.S. Army from 1988 to 1992. The round spiral patterns on the edge are inductive-edge sensor coils, and the cylindrical areas contain three voice-coil actuators.

Three years ago, MSFC produced a smaller mirror segment (to the right of the Phased-Array Mirror segment in fig. 1) based on electrostrictive actuators. Its diameter was reduced to 3 centimeters, although it has roughly the same height. Decreasing the diameter of the mirror surface makes it possible to compensate for increasingly finer scale aberrations. Reducing the height of the segment

FIGURE 1.—Several generations of adaptive, segmented-mirror technology.

lowers the overall weight of the system. The latest generation of segmented-mirror technology (in the foreground of fig. 1) is a 3-centimeter segment, less than a centimeter in height, developed by Blue Line Engineering. The size reduction has been made possible by clever mechanical linkages in the actuators. Of the several segments, only the Phased-Array Mirror, Extendible Large Aperture has edge sensors installed.

In a parallel effort, edge-sensor technologies are being advanced. The computer chip shown in the photograph (the small gray area at the very center of the circuit module) contains a complete edge-sensor electronics package developed by SY Technology, serving in place of a 3-foot by 9-inch surface-mount electronics card in the Phased-Array Mirror system and improving such features as digital and analog outputs.

The existing method of building telescopes using monolithic slabs of glass is reasonable up to a meter or so in size. Since the mass of the mirror scales with the square of the diameter, the monolithic glass approach quickly becomes too heavy for consideration for larger mirrors. Segmentation allows the weight growth to be more manageable between 25 and 40 kilograms per square meter of mirror surface. If the film technology can be improved to achieve optical qualities, the mass could be reduced to a few kilograms or less per square meter.

Most scientists agree that the next step in astronomy calls for greater resolution beyond the Hubble Space Telescope, which has a 2.4-meter primary mirror. Since resolution is proportional to primary mirror size, future science is driving the need for technologies that enable large apertures of 20 meters or greater. The larger aperture will also provide more light gathering and, as a result, the ability to see objects thousands of times more faint than ever before—maybe an extra-solar planet.

Sponsors: Office of Space Access and Technology; Center Director’s Discretionary Fund; Small Business Innovation Research

Industry Involvement: Blue Line Engineering; SY Technology, Inc.